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# REPORT ON THE UNITED NATIONS/EUROPEAN SPACE AGENCY WORKSHOP ON MICROWAVE REMOTE SENSING APPLICATIONS, HOSTED BY THE GOVERNMENT OF CHINA

(Beijing, China, 14-18 September 1994)

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# INTRODUCTION

## A. Background and objectives

1. The General Assembly adopted resolution 37/90 of 10 December 1982, endorsing the recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82) and decided, among other things, that the United Nations Programme on Space Applications should promote the dissemination of information on advanced space applications and new systems developments among Member States, particularly for the benefit of the developing countries. At its thirty-sixth session in June 1993, the Committee on the Peaceful Uses of Outer Space endorsed the United Nations Programme on Space Applications for 1994 as recommended by the Scientific and Technical Subcommittee of the Committee at its thirtieth session. Subsequently, the General Assembly, in resolution 48/39 of 10 December 1993, endorsed the activities of the Programme on Space Applications for 1994.

2. The United Nations/European Space Agency Workshop on Microwave Remote Sensing Applications was part of the 1994 activities of the Programme on Space Applications. The Workshop was co-sponsored by the European Space Agency (ESA) and organized in cooperation with the Government of China and hosted by the State Science and Technology Commission of China (SSTCC) and its National Remote Sensing Center (NRSC), from 14 to 18 September 1994, for the benefit of participants from developing countries.

3. The objective of the Workshop was to expose the participants to various aspects of current and future microwave remote sensing systems and applications of radar data to natural resources exploration and environmental monitoring. The experiences and programmes of a number of countries, particularly those from the region of the Economic and Social Commission for Asia and the Pacific (ESCAP) of the United Nations, in the development and applications of microwave remote sensing, were featured.

4. The present report, which covers the background, objectives, organization, observations and conclusions of the Workshop as well as a summary of the lectures presented (see annex I), has been prepared for the Committee on the Peaceful Uses of Outer Space and its Scientific and Technical Subcommittee. Participants will report to the appropriate authorities in their own countries.

## B. Organization and programme of the Workshop

5. The participants were professionals with several years of experience in remote sensing or in developing plans for the management of natural resources and related programmes that can benefit from the applications of microwave remote sensing. The Workshop was attended by 85 participants from the following countries/territories and international organizations: Bangladesh, Cambodia, Canada, China, Germany, Hong Kong, India, Indonesia, Japan, Malaysia, Myanmar, Philippines, Republic of Korea, Singapore, Sri Lanka, Thailand, United Kingdom of Great Britain and Northern Ireland, United States of America, ESA, United Nations (Office for Outer Space Affairs) and United Nations Development Programme (Beijing Office).

6. Funds allocated by the United Nations and ESA for the organization of the Workshop were used to defray the cost of international air travel and daily subsistence allowance of 16 participants. The Government of China, through SSTCC, provided room and board for the same participants, as well as conference facilities and local transportation for all participants.

7. Opening addresses were presented by Ms. Zhu Lilan, Deputy Director General, SSTCC, on behalf of the Government of China, by Mr. R. Schumann on behalf of ESA and by Mr. A. A. Abiodun, United Nations Expert on Space Applications, Office for Outer Space Affairs.

8. The programme of the Workshop (see annex II) was developed jointly by the United Nations, SSTCC and ESA. The Workshop was conducted through a number of plenary and working group sessions. At the latter, the participants discussed the issues associated with microwave remote sensing and concluded the sessions with the following observations and recommendations.

## OBSERVATIONS AND RECOMMENDATIONS OF THE WORKSHOP

9. The deliberations of the Workshop during its working group sessions focused on the following three major areas of microwave remote sensing: (a) data availability and accessibility, (b) practical applications of radar data, and (c) required education and training. The discussions included references to the experience acquired in satellite microwave remote sensing by the international scientific and user communities.

### A. Data availability and accessibility

10. Based on the in-depth discussions by the working group on the subject of availability of microwave data, it was the consensus of all participants that various data sources could be provided by current technology, though it may not be able to address all user needs due to the experimental nature of the technology and the inability to address all applications. With regard to data availability, the following recommendations were made in order to inform data providers of the fundamental needs of the users:

(a) Present and potential users should be more exposed to, and trained in the basic sciences that underlay microwave remote sensing technology so that they may fully comprehend the implementation of the technology and more fully utilize the relevant data;

(b) The user community should be more involved in the specification, design and development of the sensor technology in order to better address regional requirements;

(c) Acquisition of in-depth knowledge of the basic sciences that underlay microwave remote sensing technology will enable users to successfully implement demonstration programmes that could enhance the support of decision makers in expanding the utilization of data to address regional needs;

(d) Microwave sensor systems should provide data of useful quality, consistency and compatibility in such a way that it may be used repeatedly, unless constrained by other non-technical factors.

11. With regard to the discussions on improving access to microwave data to all users, the participants indicated the frustration of users in obtaining easy access to pertinent data for national or regional requirements. The following recommendations were made regarding the procedures of obtaining radar data:

(a) Better access to the data could be achieved through commercialization of the flow of data. Data providers should develop a method for users to access a standardized cataloguing and indexing system in order to easily obtain the required data, including any available historical data;

(b) To better serve the user community, cooperation and collaboration in the utilization of existing data sources in the Asia-Pacific region should be expanded in order to promote efficiency and cost-effective solutions to acquiring data;

(c) To achieve extensive utilization of the data, a multi-tier pricing policy should be instituted by providers.

12. The participants also noted that the preceding recommendations should be pursued in conjunction with the international exchange of ideas that was nurtured by the collaborative nature of the Workshop. To further this collaboration, it was recommended that a follow-on workshop be held within two years to evaluate the implementation of the recommendations put forward by the working group.

B. Practical applications of radar data

13. Participants selected three major applications areas for further discussion: disaster management, coastal and marine studies and agriculture. Participants agreed that flooding represented the most serious form of natural disaster facing the region and although some mention was made of volcanic and seismic disturbances, the detailed discussions conducted by participants primarily related to floods.

14. While the subject of the workshop was microwave remote sensing, some reservations were expressed due to the disproportionate emphasis given to synthetic aperture radar (SAR) technology. Consequently, discussions on each applications area attempted to go beyond this limitation and addressed other data sensors in order to more adequately cover the problem.

15. On the specific subject of flooding, the ability to determine flood extent and damage assessment were only part of the consideration. It was also thought important to reliably measure those parameters that were of significance in establishing a hydrologic model for flood prediction. These included soil moisture, snow cover, topography, precipitation and land cover. Requirements on these parameters were discussed with the conclusions presented in table 1.

Table 1. Flood monitoring and prediction

| Parameter | Status[a] | Resolution | Accuracy | Frequency | Delivery |
|---|---|---|---|---|---|
| Flood extent | C | 10 m (if depth required)<br>100 m (extent only) | 10-100 m positional | Daily | Real-time<br>2 days |
| Soil moisture | P | 30-100 m | +/-15% by volume | Weekly | 1-3 days |
| Snow cover | C | 30-1000 m | +/-10% | Weekly | 1-3 days |
| Topography (Interferometry or stereoscopic) | P | 30-100 m | 0.5-1 m (vertical)<br>0.1-0.2 m (coastal region) | 1 time.<br>Repeat if topographical change occurs | .. |
| Precipitation (by weather radar) | C | 30 km | - | Hourly | Real-time |
| Land cover | C | 1 km | - | Seasonal | .. |

[a]In this and subsequent tables, the status column refers to the current or expected capability to measure the parameter concerned. The letters used indicate "confident" (C) or "potential" (P).

Note: .. means not applicable.

16. Discussions on coastal and marine applications concentrated on those topics of major concern. Following presentations at the Workshop, the working group considered the detection of pollution (either from ships or shore-based industry) as the most important application. Industrial discharge into rivers was also mentioned as being of interest. Other applications considered were related to meteorology, coastline monitoring, fisheries and navigation. Although being fairly diverse, it was felt that one parameter could practically cover all of the mentioned items (see table 2).

Table 2. Coastal and marine applications

| Parameter | Status | Resolution | Accuracy | Frequency | Delivery |
|---|---|---|---|---|---|
| Sea surface | C | 50-200 m | +/-10% | 1-3 days | Real-time to 1 week |
| Oil spill and coastal pollution detection | C | 25-200 m | +/-10% | 1-3 days | Real-time |

17. The group determined that meteorological and certain fisheries and navigational applications were adequately met by current low-bit-rate products available from the European Remote Sensing satellite ERS-1, both in terms of product specification, coverage and repetitiveness. Some participants expressed concern regarding the delivery of these products within the ESCAP region.

18. Only four parameters were significant enough to be considered under agricultural applications. However, some variations in requirements of these could be anticipated, depending on the types of data available (multi-frequency, multi-polarization) and the particular classification scheme employed (general or species specific). The results of the discussion on this application are presented in table 3.

Table 3. Agricultural applications

| Parameter | Status | Resolution | Accuracy | Frequency | Delivery |
|---|---|---|---|---|---|
| Crop area | P | 5-50 m | +/-10% | 1 crop cycle | <1 month |
| Crop identification | P | 5-50 m | +/-10% | 2-4 weeks | <1 month |
| Crop condition | P | 5 m | +/-10% deviation from normal | 1-2 weeks | <2 weeks |
| Soil moisture | P | 20-200 m | +/-15% moisture by volume | - | - |

19. The participants agreed that microwave remote sensing technology has reached a level that can contribute significantly to activities of economic importance. However, with the exception of meteorological applications, the majority of those areas discussed by participants still required considerable research and support through modelling, in order to improve interpretation of the data.

20. Remote sensing technology utilizes radiation from the ultraviolet (UV) to the microwave spectrum. The potential benefits and limitations in the appropriate complementary use of all wavelength data and acquisition techniques were advocated at the Workshop.

21. It was noted that the required frequency of observation for many of the parameters greatly exceeded that obtainable from a single platform. The working group recognized that development of the necessary multi-platform systems would not be feasible from a single agency. However, given the number of systems proposed for the coming decade, cooperation and coordination between both the providing agencies and ground-reception facilities could in fact enable the repeat coverage required.*

22. It was also noted that data delivery should be considerably improved from what is currently available. This is specifically the case for those applications that require a rapid response to a given situation.

23. In this context, the working group recommended that:

(a) Agencies should attempt to coordinate the design, deployment and operation of satellite-borne instruments in order to maximize the frequency of observation of a given site and to application needs;

(b) Regional cooperation in the monitoring of natural disasters should be encouraged in order to provide data to those agencies that require it. Consideration must be given to the need for rapid and reliable distribution and the costs of providing it;

(c) Active research should be carried out in the complementary and additive use of all remote sensing methodologies. This necessarily includes research into the modelling of the various interactive processes to more fully understand information content in such data combinations;

(d) Where feasible, remote sensing applications should be moved from the research phase to pre-operational and then fully operational status.

## C. Required education and training

24. The members of the working group acknowledged that existing and planned radar-based Earth observation systems are very relevant to countries in the Asia-Pacific region, particularly for flood monitoring, forest surveys, geology, oceanographic surveys and natural disaster assessment applications. Therefore, an extensive education and training programme is needed so that countries in the region may fully benefit from airborne and satellite-borne SAR systems.

25. Some of the key education and training issues that must be addressed by Member States are: (a) who needs to be trained and why? (e.g. decision makers, professionals, technicians, educators, media); (b) how many need to be trained in each category?; (c) how long should the training be for each target group?; (d) where should the training take place? (e.g. in-house, on-the-job, locally, nationally, regionally, internationally); (e) what should be taught? (e.g. principles, techniques, applications); and (f) how should the training be funded?

26. The working group recommended that:

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*The Working Group noted that this subject is on the agenda of the Committee on Earth Observations Satellites.

(a) More training packages on microwave remote sensing should be prepared, describing principles, techniques and adapted to relevant applications. The operators of satellite-borne SAR systems should cooperate with universities and training centres to produce such packages. The training packages should be made available at the cost of reproduction to as many user agencies as possible. The United Nations system should promote their distribution in the Asia-Pacific region;

(b) More emphasis should be given to the education and training in methods of image fusion (combining optical and microwave data), in order to speed up the adoption of microwave technology, by supplementing existing operational methods of optical remote sensing. This will assist in overcoming the cloud-cover problem in the region and the complementary information content will provide synergy in the use of this information for such applications as map updating, temporal monitoring and hazard assessment;

(c) Training centres in Member States in the region should establish long-term "twinning" arrangements with advanced educational centres in the developed countries for fostering long- term, sustainable educational programmes;

(d) Specific thematic microwave workshops should be organized in the Asia-Pacific region by the United Nations, ESA, Canadian Space Agency (CSA) and other agencies to bring together relevant experts working on common problems of the region such as the use of microwave data for flood monitoring, deforestation studies, hazard assessment, environmental issues, crop monitoring and geology;

(e) Member States in the region should support the speedy establishment of a United Nations sponsored Regional Centre for Space Science and Technology Education in the Asia-Pacific region.

## Annex I

## SUMMARY OF PRESENTATIONS

### A. Future missions of the European Space Agency

1. Of the systems used to date, the European Remote Sensing satellite (ERS-1) has been operational the longest. Launched from Kourou, French Guiana on July 17 1991, it was placed into polar orbit at an altitude of 785 km (nominal) from where it continues to take its measurements. The satellite was declared operational within six months and the payload instruments have performed well within their design specifications and have maintained an overall availability of better than 95 per cent.

2. Following in the wake of the success of ERS-1, the second satellite in the series, ERS-2, completed platform integration in December 1993, when thermal vacuum testing was begun. ERS-2 will be an almost exact copy of its predecessor and will be equipped with an identical Active Microwave Instrument (AMI), which combines two instruments: a Synthetic Aperture Radar (SAR) system and a Wind Scatterometer. The satellite is also equipped with a Radar Altimeter and Microwave Sounder in its predominantly microwave payload. The main changes that have been incorporated into the ERS-2 configuration become apparent in the optical elements of its instrumentation. Modifications have been made to the Along Track Scanning Radiometer (ATSR-2) to include three visible channels, thus adding vegetation and possibly atmospheric studies to its previous capabilities in the field of sea-surface temperature measurement. Addressing established concerns over human activities and their effects on the atmosphere, the inclusion of a completely new element to the instrument payload, the Global Ozone Monitoring Experiment (GOME), and the expansion of the mission objectives to include atmospheric studies, are also confirmed.

3. GOME is a spectrometer, scanning across track over the wavelength range 240-790 nanometres, splitting the received signal into four optical paths. By analysing the four spectra so obtained, it is possible to retrieve measures of the atmospheric constituents absorbed within this range. The most important of these is ozone, but other molecules are, at least in principle, also detectable. Other applications relating to cloud coverage and aerosol content may also prove possible.

4. With the launch of ERS-2 scheduled for late 1994 or early 1995, there is a possibility of a period of tandem operation of the two satellites, assuming the continued good status of ERS-1 and the availability of funding to support it.

5. Unlike ERS-1's multiple mission phases and repeat cycles, ERS-2 will operate in a single, 35-day repeat cycle for its entire planned operational life. Joint operation of the two satellites, with either one- or eight-day separation of visits by each to a given ground site, will require that ERS-1 is once more placed into a 35-day repeat cycle to match that of ERS-2. Given the fact that ERS-1 and ERS-2 are virtual twins, the new satellite can be expected to have a similar lifetime and performance to that of its predecessor, launch permitting. Both will use what is essentially the current operational ground segment, but modifications will be made to accommodate differences in instrumentation and the fact that it was not originally designed to handle two satellites simultaneously.

6. The environmental and meteorological emphasis of these two missions will be further strengthened by the Polar Orbiting Earth Observation Missions (POEOMs). Both the currently planned satellites in this series will carry a greatly expanded payload, covering the range of wavelengths from the ultraviolet to the microwave.

7. ENVISAT-1, the first of the two, is scheduled to follow-on directly from ERS-2 in 1998 with an anticipated operational life of four years. Five of the nine remote sensing instruments on this satellite have atmospheric applications, which illustrate the goal of the strengthening of this area as the primary mission objective.

8. Other requirements of the mission are to ensure some data continuity with the ERS missions of the early-to-mid 1990s. This will be addressed by the Advanced SAR (ASAR) and Radar Altimeter-2 instruments, which will be direct developments of those flown on the earlier satellites. Proposals for the ASAR will enable it to acquire data at varying incidence angles, swath widths and spatial resolutions, with the additional capability of acquiring with alternating HH or VV polarizations. Wave mode will continue to be supported.

9. Though the scatterometer will not be included on the ENVISAT mission, some wind and wave measurements will still be provided by the new altimeter. Modifications to this will enable it to track altitude and reflectivity over land in addition to the current abilities over ocean and sea ice.

10. The second satellite of the POEOM series will be METOP-1. This collaborative effort between the United States of America and Europe will have operational meteorology as its main objective. Beyond this requirement, additional instruments will address the subjects of climate monitoring, search and rescue, and studies of the space environment, within which some continuity of data and purpose of the earlier ERS and ENVISAT satellites will also be provided.

## B. Overview of Canada's GlobeSAR programme

11. Canada, through the Canada Centre for Remote Sensing (CCRS), in cooperation with the Canadian Space Agency (CSA), the International Development Research Centre, Intera Technologies Ltd., Innotech Aviation, and Radarsat International Inc., is conducting a project in which airborne SAR imagery has been collected in Europe, Western Asia, Africa and the Asia/Pacific region. The three-year project has been named GlobeSAR. Participating countries include China, Jordan, Kenya, Malaysia, Morocco, Thailand, Tunisia, Uganda, United Republic of Tanzania and Viet Nam. In total, some 65 agencies, universities and departments are participating in GlobeSAR, the prime purpose of which is to increase the capability of the participating countries to use RADARSAT data in resource applications for planning, development and land-use management.

12. Identified research sites in each of the participating countries cover important terrain and vegetation conditions and represent research priorities for the countries. The initial stage of the programme was the data collection flight, carried out in the autumn of 1993. The data collected is being used to simulate RADARSAT data and thus familiarize users with the capabilities of this Canadian satellite, to be launched in early 1995. Through GlobeSAR, participants will have the expertise to be able to take advantage of RADARSAT data as soon as the satellite is operational.

13. Technology transfer and skills development are a primary aspect of GlobeSAR. To this end, the data collection stage was carried out with joint investigation of applications by researchers from Canada and the host countries. This is being followed by a multi-year training and development programme, based on a series of workshops which will be given in each country. The first workshops were combined with the initial planning missions in June-July 1993, the second were held at the time of the data collection flight, and the preliminary analysis workshops conducted from June to September 1994. Workshops in succeeding years are planned to become progressively more image processing and analysis-oriented.

14. Countries participating in GlobeSAR have placed a priority on utilizing modern techniques for future growth and development. Through their participation, they are committed to see this project through to a

successful conclusion. Radar imagery from GlobeSAR applications sites will be presented from the regions and will show the relative applicability of radar to various uses.

C. Development of microwave remote sensing technology in China

15. In China, microwave remote sensing technology has been under development since the 1980s. A wide range of microwave remote sensing systems are now operational and practical applications of the technology are widely used for the benefit of national economic development. There is an adequate number of personnel that are well-trained and educated in the relevant disciplines.

Development of microwave sensors

16. Both active and passive microwave sensors, including those types described below, are in use in China:

Radiometer: Many research institutions/organizations in China are involved in the development of radiometer systems. For example, the airborne 8 mm image radiometer, the airborne 15 cm image radiometer and the airborne X-band scanning radiometer have been designed by the Changchun Institute of Geography, Chinese Academy of Sciences. The microwave radiometer onboard the "Fengyun-III" satellite was designed by No. 504 Institute/Chinese Astronautics Corp. Several national universities are also working on radiometer development programmes;

Microwave scatterometer: An X-band ongoing scatterometer has been designed by the Electronic Physical Institute, Shanghai Science and Technology University. An airborne scatterometer/radiometer is now being made by the Space Application Center, Chinese Academy of Sciences, and a spaceborne scatterometer is being designed by No. 504 Institute/Chinese Astronautics Corp.;

SAR: The first Chinese SAR system was produced in the late 1970s. An airborne SAR system is now operational at the Institute of Remote Sensing Applications, Chinese Academy of Sciences, and a real-time processor was recently developed. A satellite-borne SAR system is currently under development by the Chinese Academy of Sciences and the Chinese Astronautics Corp.

Development of microwave remote sensing applications in China

17. Microwave remote sensing applications are being developed in conjunction with the development of sensor hardware systems. The national focal point of these activities is the Institute of Remote Sensing Applications, Chinese Academy of Sciences, which has conducted several studies on the subject, including a study on "Airborne SAR remote sensing experiment research", that was sponsored by the State Science and Technology Commission of China, and a study on "Radar image analysis and geological application research", sponsored by the Chinese Academy of Sciences. There are many other scientific and research organizations conducting work in the field of microwave remote sensing applications for the benefit of national economic development. The main application fields in China include:

Oceanography: sea temperature, wind velocity, inner waves, sea pollution, red tide, coastal environment and sea ice monitoring;

Meteorology: meteorological prediction, climate evolution, natural disasters and atmospheric dynamics;

Hydrology: soil moisture monitoring, drought prediction, snow and rainfall prediction;

Agriculture: crop classification and assessment, forest biomass;

Geology: geological and mineral survey, oil exploration and development, structure study, seismic disaster and geo-evolution;

Disaster monitoring: real-time monitoring of floods, forest fires etc.

Further development of microwave remote sensing in China

18. In the future, microwave remote sensing in China will focus on the needs of national economic development. There is a need for international cooperation to develop advanced information acquisition and processing technology, and for the launch of several operational radar Earth observing satellites. Thus, the major goals of Chinese policy in this area are:

Advanced technology development: Development of advanced technology in order to improve Chinese microwave remote sensing research and development programmes, and to promote applications of space technology in the area of environmental monitoring and resource management;

Developing of space-borne microwave sensors: The national 863 Hi-Tech Programme is exploring the design, manufacturing and applications of Chinese spaceborne-SAR systems. Some relevant organizations are exploring development of a spaceborne multi-mode microwave sensor. The launch of the first Chinese spaceborne microwave sensor is planned before 2000;

Exploring the marketing approach to microwave remote sensing applications: Basic research programmes should lead to promotion of practical applications in different fields relevant to the national economy. Operational microwave remote sensing systems will be developed so that China may enter the international market for radar data and services and to benefit the country's economic development;

Strengthening international scientific exchange: Due to the rapid development and spread of microwave remote sensing technology, international scientific exchange should be strengthened and expanded.

## D. Applications of microwave remote sensing data in India

19. The applications of microwave remote sensing data in India are at a different stage of development compared to the applications of optical remote sensing data. The applications in optical regions have acquired an operational status in many areas of natural resources survey monitoring and management in India. However, the use of microwave radar remote sensing data has not acquired similar status. The development of applications of microwave remote sensing data is summarized below.

Land resources applications

20. The first application-related activity in India was a temporal study of rice paddies carried out using a ground-based 9.4 GHz scatterometer. Very good correlation between the scattering coefficient and the different growth stages was observed. The study of interaction with crops and soils was initiated during the 1980s by the development of a ground-based scatterometer operating in the 1-18 GHz range. The system is presently installed at the agricultural farm of the Indian Agricultural Research Institute in New Delhi. It is used for carrying out controlled experiments in soil moisture and crop identification studies.

21. The X-band SLAR developed at Space Applications Centre (SAC) and at the National Remote Sensing Agency (NRSA) along with the X-band SAR campaign of Intera Technology, Canada, has provided useful data for feasibility studies on soil-moisture detection and land-cover mapping. The X-band SLAR has shown clear discrimination between features such as castor, cotton, habitation, fallow fields and water bodies. The experimental investigations on X-band SAR have shown the discrimination possibility between crops such

as rice and sugar cane. The indigenously developed C-band airborne SAR instrument's data has provided much needed momentum. Its flights over Ahmedabad have provided the data for the purpose of urban land use and urban sprawl mapping using visual interpretation.

22. With the availability of ERS-1 SAR data, significant progress has been made in major areas such as soil-moisture detection/estimation, crop identification, geological mapping, exploration for hydrocarbon bearing structures etc. Several specialized software packages related to segmentation and filtering have been developed at SAC. The sensitivity of ERS-1 SAR data for soil-moisture variation has also been exploited for demonstrating its use in applications such as canal-water seepage, delineation of agricultural irrigated areas, irrigation information, identification of water-deficit areas, and for generating shallow water tables. The applications of ERS-1 SAR data have also been taken up within ISRO for assessing the potential for forestry applications. It was observed for an area covering parts of the Agra district that ERS-1 SAR data was able to provide classification accuracies comparable to those provided by data from optical sensors.

23. One of the most important types of information required is the nature and extent of damage caused by floods. The ISRO Department of Space has initiated systematic work on the possibility of monitoring the extent of floods using ERS-1 SAR data. Snow-pack water resources are of considerable significance in the management of irrigation systems, flood-warning systems, hydro-electric power schedules and regional water-supply systems. The Department of Space has also initiated experimental observations covering parts of the Himalayan region using data from ERS-1 SAR, SIR-C and X-SAR.

24. The data from SIR-A and SIR-B were utilized for understanding the microwave signatures of various objects. They were further used for identification of geological structures and lithology. ERS-1 SAR data was used in conjunction with IRS LISS-II optical data to prepare geological, geomorphological, lineament and tonal/textural maps of the Pur, Benera and Jahazpur areas of Rajasthan. The data obtained from non-imaging sensors have also been utilized for land resource applications. The GEOSAT altimeter data for the western coastal region were analysed for the generation of geoidal anomaly contours and the related density sliced geophysical images. These images were used to assist off-shore oil exploration

Ocean resource applications

25. The application of microwave radiometers for deriving various ocean-related information, such as sea-surface temperature and sea-surface winds, has now matured to a stage where it provides accurate measurements of these parameters on an operational basis. Indian national scatterometer and altimeter instruments for oceanographic applications are presently at the development stage.

26. The use of altimeter data for oceanographic applications was initiated in India with the launch of GEOSAT. Along with several routine applications, the GEOSAT altimeter data were used for the detection of charted and uncharted sea mounts in the Indian Ocean. The information on sea mounts is useful in deep-sea circulation studies, submarine navigation, locating fishing grounds and deep-sea mining. Advanced signal processing techniques and geopotential theories were developed for these detection activities.

27. With the launch of the ERS-1 satellite, the data obtained from its SAR, scatterometer and altimeter instruments have provided an impetus to other oceanographic applications in India. A number of scientists at SAC are presently working on the data obtained from these sensors. The ERS-1 scatterometer data are being used to generate weekly/monthly average maps of wind vector fields over India. The algorithms necessary for wind vector solutions and wind directional ambiguity removal have also been developed as has a methodology for cyclone parameter determination. The ERS-1 altimeter data, in conjunction with ERS-1 scatterometer data, are also utilized for the forecast of wave conditions in the seas around India. A computationally efficient numerical technique has been developed for the numerical model used for the

forecasts. The ocean wave forecast model proved to be very useful for advance planning of offshore and fisheries operations, ship routes, naval operations and the structural design of offshore/coastal installations.

28. The study of internal waves (subsurface waves found at depths of from tens to hundreds of metres) is also one of the significant oceanographic applications of SAR data being pursued in India. Internal waves manifest themselves in the form of distinct modulations of surface wave fields and hence are reflected clearly in a SAR image. Under an ESA/ISRO project, the data from ERS-1 SAR and IRS-1 LISS on cloud-free occasions are analysed to examine the different aspects of internal waves in the Andaman Sea.

### E. Applications of radar technology: the Philippine experience

29. With the development of radar technology, microwave remote sensing data has proved to be a valuable tool for data acquisition in tropical countries such as the Philippines where cloudy conditions prevail almost throughout the year (in the Philippines, there are only about 22 cloudless days in a year. With these weather limitations, it is estimated that it would take more than 10 years to complete cloudless aerial photography coverage of the country, and much longer for optical satellite coverage). At present, applications of airborne SAR data in the Philippines are widely used for disaster/hazard monitoring and assessment, and topographic base mapping.

30. On 12 June 1991, the provinces in central Luzon, specifically the Pampanga and Tarlac provinces, were severely affected by the eruption of the Mount Pinatubo volcano. Natural and man-made resources such as infrastructure were heavily damaged and required billions of pesos for rehabilitation. Attempts were initially made to use both aerial photography and optical satellite data for damage assessment. However, because of cloud-cover problems, their use was limited. Thus, the National Mapping and Resource Information Authority (NAMRIA) proposed the use of airborne SAR systems for the immediate acquisition of images of the affected areas.

31. The system selected was the STAR-1 of Intera Technologies, Ltd., a lightweight, digital, fully-focused X-band SAR carried in a twin prop-jet Cessna Conquest aircraft. Out of the 30 million hectares of land area of the entire archipelago, 10,621,757 hectares were covered by the SAR survey which was undertaken by Intera. The primary objective of the SAR survey was to facilitate the immediate acquisition of data and information necessary for the immediate rehabilitation and monitoring of devastated areas of the country. In addition, these SAR acquired data were used also in the implementation of other development projects related to the management of the environment.

32. One of the major projects implemented and completed with the application of radar technology using the STAR-1 SAR system was the "Utilization of SAR data of northern Philippines (Luzon region) for earthquake damage assessment and geohazard classification". The project was implemented in 1991 with funding from the World Bank and the Asian Development Bank (ADB). Among the information derived from the radar data were the location of local slumping and land scours; mapping of rock falls, rock slides and soil slides; detection of mud flows through liquefaction of muds on high slopes; mapping of offsets in lithologic units, geologic structure, geomorphic and cultural features; identification of areas of unconsolidated surface material prone to liquefaction; and proximity of unconsolidated surface material to faults or a high density of surface fracture lineaments.

33. In addition, Intera conducted a two-week training programme for user institutions in order to provide them with additional information on the products available. Another two-week training programme with emphasis on the specific use of SAR for earthquake hazard mapping that involved geologic, geotechnical and geophysical aspects in earthquake assessment, micronization, seismic coding and geohazard classification was also organized.

34. Phase II of the project involves the preparation of geologic, seismic zonation and geohazard maps covering approximately 9.3 million hectares of Luzon. This project is under development in collaboration with the Geotmatrix Consultant Group from the United States of America. It is expected that the project will produce geohazard maps of selected areas, and detailed geohazard and seismic zonation maps for two urban areas which will include: (a) variations in ground-shaking potential; (b) potential for liquefaction; and (c) potential for landslides. Training on state-of-the-art geotechnical technology for evaluating earthquake hazards and seismic micronization will also be provided as part of the project.

35. SAR data are widely used by NAMRIA in its project on "Resource mapping of the Philippines", which is being conducted as a part of the National Mapping Programme. This programme will result in production of a new topographic base map series of the Philippines, at a scale of 1:50,000, covering an estimated area of 21 million hectares, or about two thirds of the total land area of the country. This is extremely important for national development, due to the fact that existing base maps, especially for Visayas and Mindanao, are already 40 years old and, therefore, outdated not only in terms of information but also in format. While aerial photographs will still be the main source of information, SAR data are expected to provide supplemental information for areas that are perennially cloud-covered. This project will run for a period of 10 years in conformity with the international standard revision cycle for base maps.

36. The Philippine Atmospheric, Geophysic and Astronomical Services Administration (PAGASA) is currently implementing a pilot project on the "Application of SAR data in flood hazard assessment of fluvial and coastal environment". ERS-1 data will be used to map the extent of flooded areas and to monitor land-use changes in and around flooded areas. The study area is the Bicol River Basin in Southern Luzon.

37. A research study on the use of ERS-1 SAR data is also being undertaken by the University of the Philippines Training Centre for Applied Geodesy and Photogrammetry (UPTCAGP). The project, entitled "Application of ERS-1 SAR data for environmental degradation assessment in the Mt. Pinatubo area and vicinity", aims to produce land-cover maps of the area. The first approach will utilize multitemporal SAR imagery to provide a basis for developing relationships between radar backscatter and ground features. The second approach will utilize SAR data in combination with other remotely sensed data, such as SPOT.

38. The last two projects are conducted in cooperation with the European Community (EC) and ESA.

## F. Applications of radar data in agriculture and land-use management in Thailand

39. Since Thailand's ground receiving station was upgraded to receive ERS-1data in March 1993 and JERS-1 data in October 1993, applications of SAR data have been enlarged to include disciplines such as forestry and land use. The development of SAR systems for all-weather and all-season observation has led to increased interest in remote sensing applications. Due to insufficient development of specific algorithms for SAR data classification, data from several different types of sensor are combined for certain applications in Thailand, including surface changes studies, crop-type identification and land-use monitoring.

### Application of SAR data for studies of coastal areas

40. The purpose of this study was to evaluate the potential applications of SAR data in comparison with Landsat TM data in coastal areas of Thailand. The study area covered the western part of Bangkok between latitude 13° 10' - 13° 25' N and longitude 99° 45' - 99° 59' E in certain parts of the Samut Songkram and Phetburi provinces. In general, the topography of the area was characterized by young delta, old delta and terrace features with approximate elevation from 1-350 m above sea level. Land-use features consisted of paddy fields, mixed orchards and shrimp ponds.

41. JERS-1 SAR and Landsat TM data acquired on 6 June 1992 and 2 November 1991, respectively, in the form of Computer Compatible Tape (CCT), were used for the study. Image processing of the data sets was carried out by using a Meridian Image Processing system. In preparation for image identification, SAR data were processed by standard filtering. Image registration was performed on Landsat TM data for geometric correction. Three ground-control points were selected to be spatially warped to a 1:50,000 Universal Transverse Mercator map projection by using cubic convolution algorithms to 12.5 m x 12.5 m pixel size.

42. This study produced satisfactory results with regard to identification of water content, mangrove forests, shrimp farms, field preparation for paddy cultivation, as well as urban areas, railways, roads and canals.

Application of SAR data for studies of urban areas

43. The main objective of this study was to examine the types of information that can be obtained from JERS-1 SAR data. The selected study area was Bangkok and its vicinity, which covered a region of about 700 square kilometres in the upper part of Bangkok and part of Nonthaburi and Pathumthalli. General land-cover types were urban, mixed orchards, swampy area and marsh area.

44. The data used in this study were JERS-1 SAR data acquired on 25 June 1992, at 12.5 m image resolution; LANDSAT TM data acquired on 28 May 1992; and SPOT panchromatic imagery acquired on 7 December 1989. The Landsat TM data bands 3, 4 and 5 were geometrically corrected using 1:50,000 topographic maps as a reference and were merged with JERS-1 SAR data as an image for image registration. To reduce noises on the SAR image, 3 x 3 median filtering was applied using the Meridian Image Processing system.

45. It was found that some confusing categories such as urban areas and swampy areas could be clearly separated on SAR-VIR colour composite due to the roughness characteristics of the objects. For agricultural applications more details on vegetation condition could be detected with the merged SAR-VIR image. Mixed orchards with different canopy characteristics (homogeneous and heterogeneous) could also be separated on this merged SAR-VIR image.

Utilization of SAR data for crop studies on the eastern coast of Thailand

46. The objective of the study was to evaluate ERS-1 SAR data for tropical crop identification and to develop methods for using ERS-1 SAR data in a complementary mode with optical remote sensing data for crop mapping. The study area was on the eastern coast of Thailand, between latitude 12° 20' - 13° 10' N and longitude 101° 10' - 101° 45' E. The topography of the area included riverine terrace, undulating and mountainous features. The major crops under cultivation in this area are rubber, mixed orchards, rice and field crops including pineapple, cassava and sugar cane.

47. ERS-1 SAR data acquired on 29 July 1993, 2 September 1993 and 18 April 1994 were used for the study. Geometric correction was applied to the July image for registering it to a Universal Transverse Mercator (UTM) projection and re-sampling using the "nearest neighbour" technique to 12.5 m square pixels and then using this image as a reference image to which all data were registered. Data analysis was conducted visually on the basis of ERS-1 SAR multitemporal data. A standard filtering technique, the median filter with a 5 x 5 window, was applied to remove speckle noise on the image.

48. The data set of SAR with 12.5 m square pixels was divided into sub-areas where it ranged from flat to gently sloping terrain. Some areas in the mountainous zone were cut off due to a geometrical mismatch between different dates of ERS-1 SAR data since the SAR data were not terrain corrected. Satisfactory results were obtained with regard to the identification of tropical crop types, patterns and texture.

## G. European Community/ESA/ASEAN ERS-1 Project

49. In November 1992 the European Community, in partnership with the Association of South-East Asian Nations (ASEAN) and with the technical support of ESA, embarked upon an ambitious, three-element project to upgrade remote sensing facilities in South-East Asia in order to assist the developing countries of the region in the development of microwave remote sensing programmes and applications of ERS-1 and NOAA-AVHRR data. This was to be provided through hardware and software upgrades for both ERS-1 and AVHRR data acquisition, processing and archiving and, in the case of ERS-1, through the establishment of pilot projects and a training programme to be conducted over a period of two and one-half years. The structure of the project comprises three elements: two bilateral agreements (with Malaysia and Thailand) aimed at providing the necessary hardware and software resources to support new developments in remote sensing within ASEAN, and one regional component addressing the pilot project and training needs required.

50. The EC grant available to the project is ECU 3.9 million with an additional ECU 1.52 million contribution of ESA in the form of data and training facilities.

51. In Thailand, upgrading of existing acquisition facilities in support of ERS-1 has been completed and operations commenced in March 1993. Since then approximately 145 high density digital tapes (HDDTs) have been acquired, each one containing data from (on average) 3 to 4 satellite passes. This suggests that there is data for some 5,000-6,000 orbits recorded by the Thai receiving station that are now potentially available for production.

52. In addition to the precision processor, capable of producing ERS-1 products to ESA specification for a variety of product types, the processing chain incorporates the first operational installation of a quick-look processor, enabling even the longest passes to be processed to image form in less time than it takes to produce a single precision product. The quick-looks produced in this way provide a valuable visualization within the cataloguing facility that is also provided as part of the overall system. To date, approximately 65 HDDTs have been successfully screened by this processor and consequently form part of the catalogue.

53. In Malaysia, upgrades are to be made in two locations. The first upgrade will be an extension to the existing AVHRR acquisition facilities at the Malaysian Meteorological Service (MMS) which will include provision of capabilities for processing of higher level products using the ESA-developed SHARK system. A second facility will also be equipped with SHARK, as well as a Universal Interface Terminal (UIT) system and Stand-alone SAR Geocoding system (S-GEOS). All software packages run on Sun architecture.

54. Further installations of the three systems addressed by this bilateral agreement are to be made, and suitable training given, in both Indonesia and the Philippines, under direct agreement between the receiving agencies and ESA.

55. Eight pilot projects have been selected from the large number of proposals submitted and these have been distributed between the four countries that are participating in the project (Indonesia, Malaysia, the Philippines and Thailand). The pilot projects are intended to address applications issues that are of specific relevance to countries of the region, with particular emphasis on the use of ERS-1 data in addressing those needs.

56. The pilot projects are: (a) INDO-1: Land use assessment and monitoring using ERS-1 SAR data; (b) INDO-2: Application of ERS-1 SAR data for coastal zone management; (c) MAL-1: Complimentary nature of SAR and optical data for land cover mapping; (d) MAL-2: Coastal zone information from ERS-1 SAR satellite data; (e) PHIL-1: Application of ERS-1 SAR data to environmental degradation assessment in the Mt. Pinatubo area; (f) PHIL-2: Application of ERS-1 SAR data in flood hazard assessment of fluvial

and coastal environment; (g) THAI-1: Rice monitoring using ERS-1 data in Thailand; and (h) THAI-2: Application of ERS-1 SAR data for coastal studies in Khlung District, Thailand.

57. To support these pilot projects, the Project also provides an opportunity for appropriate training to involved personnel. Training programmes also help to facilitate the dissemination of information on the capabilities of the relatively new technology of microwave remote sensing among the participating countries. Foreseen within this element is the need to promote an awareness among the senior decision makers about the potential advantages to be gained from using remote sensing technologies, microwave in particular, in the decision-making process. For this reason the EC-ASEAN Project has structured its training programme into a series of layers, each targeted at a different audience:

Decision makers seminars: These are one-day events, with an intended audience of up to 200 decision and policy makers, with the intent of providing a quick overview of the possible applications areas to which microwave data can be usefully applied. Each participating country hosts one of these events;

Regional training workshops: These are for a period of two weeks each and introduce an audience of 24 researchers to the principles and practices of microwave remote sensing. Each event addresses a different applications area. The means of achieving this is through a series of lectures and laboratory sessions, conducted for the most part by visiting European experts and incorporating a 1- or 2-day field trip;

National training workshops: As a result of the recent Advisory Board Meeting, the exact format of these events has yet to be determined. One possibility would be to pool available funds to provide support for the development of sets of training materials, and then organize one event to train teachers on the use of those training materials.

58. Of the events held to date, all the decision makers seminars and all but one of the regional training workshops have been completed (the remaining regional training workshop is scheduled to be held in Indonesia by the end of 1994). Beyond this, there is provision for two researchers from each project to spend a period of time, up to three weeks, in Europe, at ESRIN facilities in order to address issues that are important to the ERS programme, and at the partner institutes of their respective projects to work on pilot project data using hardware, software and expertise that may not be readily available within ASEAN countries.

Annex II

PROGRAMME OF THE WORKSHOP

| DATE/TIME | SUBJECT | SPEAKER |
|---|---|---|
| 14 SEPTEMBER 1994 | | |
| 08.00-09.20 | Registration | |
| 09.30-10.30 | Opening ceremony | |
| | Chairman: Mr. Lin Quan (China) | |
| | Welcome address | Ms. Zhu Lilan<br>Deputy Director General, SSTCC |
| | United Nations address | A. A. Abiodun (United Nations) |
| | ESA address | R. Schumann (ESA) |
| | Spaceborne radar remote sensing in the 1990s (1) | |
| | Chairmen: Prof. Chen Fangyun (China), Dr. A. A. Abiodun (United Nations) | |
| 10.30-11.00 | Microwave remote sensing technology development in China | Lin Quan (China) |
| 11.00-11.30 | ERS Future Programme | R. Schumann (ESA) |
| 11.30-12.00 | Development of national capabilities in remote sensing | A. A. Abiodun (United Nations) |
| | National Programmes | |
| | Chairmen: Prof. Chen Shupeng (China), Dr. W. Alpers (Germany) | |
| 14.00-14.30 | Results of radar research and applications programmes in India | R. C. Garg (India) |
| 14.30-15.00 | Philippines national programmes in applications of radar technology to environmental monitoring and natural resources management | J. Solis (Philippines) |
| 15.00-15.30 | Development of tools for natural resources management in Bangladesh using ERS-1 SAR data | A. Sardar (Bangladesh) |
| 15.30-15.50 | Break | |
| 15.50-16.20 | Educational aspects of introducing radar technology in Singapore | Lim Hok (Singapore) |

15 SEPTEMBER 1994

Spaceborne radar remote sensing in the 1990s (2)

Chairmen: Mr. R. Schumann (ESA), Prof. Guo Huadong (China)

| | | |
|---|---|---|
| 09.00-09.30 | Canadian RADARSAT Programme | J. McNally (Canada) |
| 09.30-10.00 | Canada's GlobeSAR Programme - An overview | F. Campbell ( Canada) |
| 10.00-10.30 | Chinese spaceborne SAR system | Zhu Minhui (China) |
| 10.30-11.00 | RADARSAT update: applications, products and market development | G. Elms (Canada) |
| 11.00-11.30 | JERS-1 and follow-on programmes of Japan | T. Tanaka (Japan) |
| 11.30-12.00 | European Community/ESA/ASEAN ERS-1 project | R. Schumann (ESA) |

Radar data processing and calibration

Chairmen: Dr. G. Sun (USA), Prof. Jiang Jinshan (China)

| | | |
|---|---|---|
| 13.30-14.00 | The new DLR SAR processor | A. Moreira (Germany) |
| 14.00-14.30 | Calibration of operational SAR systems | G. Keyte (United Kingdom) |
| 14.30-15.00 | Implementation of advanced SAR technologies for future Globe SAR programmes | W. C. Bayer (Canada) |
| 15.00-15.30 | Forest ecological studies and radar backscatter modeling | G. Sun (USA) |
| 15.30-15.50 | Break | |

Radar data applications. Session I:

Radar data applications in agriculture, forestry and environmental monitoring

Chairmen: J. McNally (Canada), T. Tanaka (Japan)

| | | |
|---|---|---|
| 15.50-16.20 | Applications of radar data in agriculture and land-use management in Thailand | R. Simking (Thailand) |
| 16.20-16.50 | Applications to environmental monitoring | M. Manore (Canada) |
| 16.50-17.20 | Forest structure from SAR imagery | K. J. Ranson (USA) |

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|---|---|---|
| 08.30-17.00 | Visit to the Department of Airborne Remote Sensing, NRSC | |
| | Visit to Institute of Remote Sensing Applications, Chinese Academy of Sciences | |

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Radar data applications. Session II:

Radar data applications to geology, mineral exploration and oceanography

Chairmen: Dr. F. Campbell (Canada), Dr. G. Keyte (United Kingdom)

| | | |
|---|---|---|
| 09.00-09.30 | Applications of radar remote sensing in natural resources investigation and management | Guo Huadong (China) |
| 09.30-10.00 | Imaging ocean by ERS-1 SAR | W. Alpers (Germany) |
| 10.00-10.30 | Sea and ice monitoring using SAR | S. Jiancheng (USA) |
| 10.30-11.00 | Break | |
| 11.00-11.30 | Progress in applications of SAR data in Indonesia | K. Mahdi (Indonesia) |
| 11.30-12.00 | Image fusion of optical and microwave satellite data for Earth sciences applications | J. van Genderen (ESA) |

Radar data applications. Session III:

Radar data applications to meteorology, climatology and disaster monitoring

Chairmen: Li Deren (China), R. Schumann (ESA)

| | | |
|---|---|---|
| 13.30-14.00 | Applications of space technology for natural disasters monitoring | Jiang Jinshan (China) |
| 14.00-14.30 | Break | |

14.30-19.00 Working Groups session:

(i) Working Group on data availability and accessibility

Chairmen: K. Mahdi (Indonesia), W. C. Bayer (Canada)
Rapporteurs: Lu Xiao Qing (China), V. Sicat-Alegre (Philippines)

(ii) Practical applications of radar data

Chairmen: R. Schumann (ESA), Lim Hok (Singapore)
Rapporteurs: R. Simking (Thailand), J. Ab Talib (Malaysia)

(iii) Required education and training

Chairmen: Li Deren (China), J. van Genderen (ESA)
Rapporteurs: Luo Xianyuan (China), Huang Yong Hong (China)

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09.00-10.00 Working Groups session (continued)

10.00-11.00 Workshop discussion

Chairmen: Dr. A. A. Abiodun (United Nations), Lin Quan (China)

(i) Report by Chairmen of the Working Groups sessions

(ii) Discussion on the reports

(iii) Adoption of the reports of the Working Groups

11.00-11.20 Break

11.20-11.45 Summary and evaluation of the Workshop — A. A. Abiodun (United Nations)

11.45-12.15 Closing ceremony

Chairman: Ma Junru (China)

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|---|---|
| Closing address | A. A. Abiodun (United Nations) |
| Closing address | V. Hood (ESA) |
| Closing speech | Xu Guanhua<br>Deputy Director<br>Academy of Sciences of China |